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NAVY TELEMEDICINE: CURRENT RESEARCH AND FUTURE DIRECTIONS

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20040112 018

Report No. 02-35

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Navy Telemedicine: Current Research and Future Directions

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Report No. 02-35 was supported by the Office of Naval Research, Arlington, VA, under Work Unit No. **637060N M2332.001-60004**. The views expressed in this article are those of the authors and do not necessarily reflect the official policy or position of the Department of the Navy, Department of Defense, or the U.S. Government. Approved for public release; distribution unlimited.

Human subjects participated in this study after giving their free and informed consent. This research has been conducted in compliance with all applicable Federal Regulations governing the Protection of Human Subjects in Research.

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Summary

Problem

The ongoing war on terrorism makes medical surveillance and remote access to medical care for deployed forces pressing concerns. The potential for chemical and biological terrorism on U.S. soil adds an urgency for Navy medical technologies to respond to Homeland Defense concerns, as well. An assessment of Navy telemedicine as a complex healthcare support system is needed to demonstrate how current practices, training, equipment, and expenditures measure up to the emerging needs of the Fleet.

Objective

This report reviews military and civilian models for evaluating telemedicine systems in order to determine future directions for Navy telemedicine research within the current funding environment. How can we calculate the level of technology to implement for the most productive return on investment across varying treatment settings?

Approach

A literature review of military and civilian telemedicine was conducted in September 2001 to determine what types of evaluative models are currently being advocated by telemedicine practitioners. A review of current models for evaluating telemedicine yielded seven categories for evaluation: tools and equipment; outcomes; cost; treatment settings, task domains; participant satisfaction; and human factors.

Using this literature review as a baseline, the authors developed a conceptual model for assessing the structure of Navy telemedicine. The model describes how each of the seven components affect the implementation of telemedicine in Navy and civilian settings. Finally, the authors recommend how short-term, narrowly-focused studies could form the basis for a model for correlating level of technology suites to level of care across treatment settings.

Results

An analysis of models for evaluating telemedicine indicates that there is currently no workable model for evaluating telemedicine as a complex and multi-level system, either in military or civilian research. While military telemedicine circumvents some problems faced in civilian systems, issues such as wait and queue, connectivity, continuum of care across variable treatment sites, and healthcare needs in deployed platforms make it difficult accurately to measure the effectiveness of telemedicine at different levels of care.

Conclusions

A model for evaluating telemedicine that correlates level of technology to level of care should be developed. A system of measurable criteria for determining the appropriate telemedicine suite to implement for a given population at risk across varying treatment facilities needs to be designed so that the maximum return on investment can be achieved.

1.0 Introduction

Telecommunications technologies—long an integral part of medical support for the U.S. armed forces—have increasingly become the standard of support in serving a treatment population at work in varied environments. Personnel may be deployed in combat, peacekeeping, or humanitarian efforts in environments that are relatively inaccessible or remote from conventional military healthcare resources, or that pose special challenges because of harsh conditions (Vidmar 1999). The ongoing war on terrorism makes medical surveillance and the ability to provide immediate medical care to these deployed forces an even more pressing concern. Given the enormous investment the DOD has made in implementing telemedicine (\$327 million between 1993-1998), how can we determine that we have efficient systems in place to serve our troops (Reed 2002)?

The Naval Health Research Center (NHRC), San Diego, CA, has an established history of research evaluating the potential impact of advanced telecommunications for shipboard medical departments. Even before the Navy issued specific directives to do such research (Patel 1994; Fisher 1994; Tillery 1995), Nice (1987) documented Navy medical communications and medical evacuations (MEDEVACs) aboard ships at sea, concluding that telecommunications technologies could greatly reduce the incidence of medevacs and improve quality of care at sea. The medical personnel interviewed as part of that study believed that x-rays and image transmission would have been the most useful forms of telemedicine for them at sea. Senior medical personnel estimated that 28% of medevacs could have been avoided with appropriate telemedicine.

Following the 1994 and 1995 directives, NHRC researchers continued investigating and evaluating telemedicine in studies focusing on equipment and training needs, treatment sites (such as aboard ship); and specialties such as telemental health and Ear/Nose/Throat (ENT). Gauker, Pugh, and Pearsall (1995) used independent duty corpsmen (IDC) rankings of telecommunications technologies for their utility in Navy healthcare and concluded that telemedicine could be effective if based in careful planning, training, and evaluation. IDC providers surveyed as part of this study ranked basic modes of communication over complex ones for use in their shipboard medical problems. In order of preference, the technologies were telephone, radio, fax, email, x-ray, still pictures, and VTC.

Larson, Burr, Pearsall, and Silva (1998) analyzed self-reports from Navy telemedicine users on board aircraft carriers and found that shipboard providers perceived telemedicine—especially low-end technology—as a clinically effective tool. This survey of medical providers found that VTC and Internet based modalities were frequently used for dermatology or orthopedic questions. Telemedical consults changed 39% of treatment plans, a finding which suggests these consults have substantial clinical impact.

Lane, Swistak, and Konoske (1999) evaluated the medical workstation (MEWS) during field-testing exercises during Kernel Blitz 99 to determine whether the equipment increased provider satisfaction, productivity, medical readiness, and clinical capabilities at far forward and remote areas of care. The MEWS system consists of small computer stations and provides real time, far forward medical data that can be stored and transferred. Providers were generally satisfied with the system, itself, and its productivity for their care. Power outages compromised the reliability of system operation and decreased some providers' ratings. Provider comments strongly suggested that any system implemented should support, rather than change, the normal workflow of providers at far forward echelons of care in order to ensure utilization.

Melcer and colleagues evaluated factors influencing the development of a telemedicine network in medical treatment facilities (MTFs) of Region 9 onshore, focusing on the clinical impact of telemedicine for ENT specialty care. In a retrospective study (Melcer, Crann, Hunsaker, Deniston, & Caola, 2002), a new telemedicine network using VTC for consults and a web-based application for scheduling sessions showed substantial growth in the rate of telemedicine use over a 2 year period. The ENT specialty showed the largest increases in rate of use relative to neurology and child psychiatry. In a prospective study (Melcer, Hunsaker, Crann, Caola, & Deniston, 2002) ENT telemedicine via VTC produced substantial clinical impact, with approximately 45% of consults leading to a change in diagnosis. This rate of diagnosis change generalized across patient demographic and type of ENT condition.

The purpose of NHRC telemedicine studies to date has been to assess the need for and clinical impact of medical telecommunications ashore and afloat, and to evaluate whether telemedicine applications utilized in MTFs on shore might generalize to shipboard medicine. The variables examined have necessarily been limited so that the available data could provide clear answers to narrowly defined research questions. Thus, a complex system of healthcare delivery has largely been studied as a series of separate applications operating as parallel platforms. A model has not yet been developed to account for Navy telemedicine as a dynamic system that relies on interoperability among hardware, software, personnel, and data.

Purpose of this report

This literature review has three objectives:

- Review models for evaluating telemedicine systems in the current literature
- Ascertain key criteria proposed for assessing telemedicine systems
- Compare military studies to date with proposed models to determine new directions for Navy research in the current funding climate

An assessment of telemedicine as a complex system is needed to demonstrate how current processes, usage, training, equipment, and expenditures measure up to the emergent needs of the Fleet as a whole. Assessing telemedicine as an integrated system of healthcare delivery would simultaneously account for organizational and technological factors in order to evaluate how information gets distributed and processed. This type of analysis would extend the concept of technical interoperability—the ability of software and hardware to exchange information and share tasks and resources—to human and organizational structures. The most important research focus for the foreseeable future, then, would be to address how technical configurations and organizational structures affect the flow of information and resources in a given telemedicine system. Evaluating the degree of technical interoperability and the organizational ability to pool knowledge and resources in a system can help ensure that that each system is deployed to its maximum capacity.

Structure of this report

This study was conducted primarily by reviewing telemedicine literature that did one of three things: proposed a theoretical model for evaluating the effectiveness of telemedicine; described an existing telemedicine program; or attempted to measure outcomes of key components of telemedicine systems. Section 2.0 describes how the authors of this report selected the articles reviewed in this report. Section 3.0 discusses the applicability of civilian models to military telemedicine. Section 4.0 discusses seven key criteria for assessing telemedicine systems suggested by researchers in both civilian and military telemedicine. This section also describes programs or studies that reflect the focus and potential of each assessment model. Although long-term, rigorous empirical studies are relatively rare, the authors have attempted to provide data-driven studies wherever available. Section 5.0 recommends new directions for Navy research and suggests possible structures for follow-up studies, while Section 6.0 sums up important shifts in focus in telemedicine assessments.

2.0 Method

A literature review was conducted in September 2001 in the library database PubMed using the search term "telemedicine" in combination with "evaluation" or "model." The search yielded 602 empirical and non-empirical evaluations of telemedicine, 69 of which evaluated telemedicine in military settings. Studies that assessed specific products that had become outdated or underused were eliminated from consideration so that only models for evaluating technologies likely to be in general use were reviewed. The abstracts of the remaining articles were then reviewed and sorted by the type of evaluation each performed or advocated (i.e., cost/benefit analysis, provider satisfaction assessment, and so forth). Technical reports available through the NHRC library and the Defense Technical Information Center (DTIC) were analyzed using the same method.

Since the articles reviewed in this search were largely written by MDs, a related literature search was conducted via the PubMed and the DTIC databases during September 2001 using the search term "telenursing" to get a preliminary indication of the perceptions of medical providers such as nurses and IDCs. Some 143 article abstracts were read and sorted as previously described. The volume of articles in this area suggests the viability of a separate study comparing the experiences of nurses and IDCs. The telenursing articles were thus omitted from this review in order to focus on less specialized models for evaluating telemedicine. For the purposes of this report, the telenursing articles would have formed a sizeable subset of the "human factors" category discussed later in this report.

The authors of this report designated a function or type for each article reviewed, as follows.

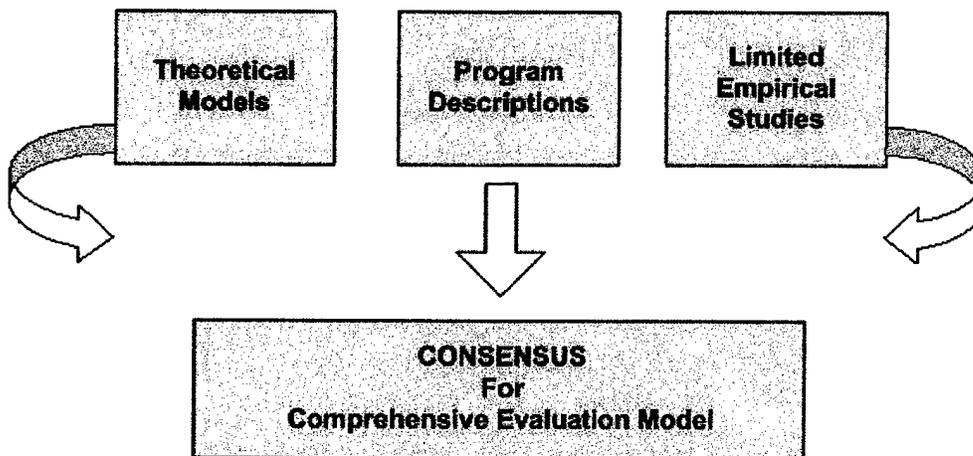
- Structural analysis or model for a potential program

Articles in this category described a theory, philosophy, or structure that the telemedicine literature, current state of technology, or experience with telemedicine implemented to date suggested.

- Description of the progress of an existing program
Articles in this category described the equipment, staffing, logistics, or other “nuts and bolts” aspects of a specific program. Little or no data was collected in support of a specific research question. The primary focus was how a particular program functioned.
- Empirical analysis of data from existing program
Articles in this category analyze data from surveys, rate of equipment usage, treatment outcomes, and similar, quantifiable factors in an up-and-running telemedicine program. Most of the work done at NHRC falls into this category.

In the following review of evaluative studies in telemedicine, the function of each article (structural, descriptive, or empirical) has been designated as well as the type or focus of the evaluation. Table 1 summarizes the types of models, program descriptions, and short-term empirical studies that attempt to define how telemedicine systems currently work.

→ **Types of Articles Reviewed**



Outcomes of Literature Review.

The authors of this report identified an extensive number of evaluative models, descriptions of the implementation of specific telemedicine projects, and studies that attempted to assess the efficacy of specific components in larger telemedicine systems. Analysis of these revealed recurring (advocated in more than five documents) proposals for or demonstrations of specific types of evaluation:

- Assessments of tools and equipment
- Integration or outcome studies
- Cost analyses

Although not as prevalent in the telemedicine literature, the following categories of evaluation were also advocated as part of an integrated evaluation of telemedicine systems:

- Evaluations of telemedicine treatment settings
- Task domain studies
- Evaluations of participant satisfaction
- Human factors evaluations

These seven categories appear to comprise a consensus in the literature regarding which components should be assessed in evaluating the structure of telemedicine as a system. The authors of this report read model proposals, program descriptions, and short-term empirical studies (when available) from each of these seven categories and summarized examples representing each type of evaluation for inclusion in this report. In addition to these studies of the individual components of telemedicine systems, the authors reviewed articles that attempted to construct broad-based models for evaluating how these components work together as a complex system. A working list of criteria for evaluating telemedicine as a complex system was constructed for the purposes of this report by combining the comprehensive model suggested by Yawn (2000) with human factors criteria advocated in Yellowlees (1997, 1998).

Table 2 lists the criteria for evaluating telemedicine systems that have been repeatedly proposed in the literature and summarizes representative studies in each of the seven categories in order to suggest their applicability to military telemedicine.

Table 2. Criteria for Assessing Telemedicine Systems

Criteria for Assessment	Study Types	Representative References	Outcomes
Task Domain	Evaluative Model	Grigsby et al. (1995)	List of healthcare processes for evaluation (e.g., patient education, urgent evaluation)
Military Utility Limited. May be useful when developing a technology.	Empirical Study	Potter et al. (1997)	Derm specialty most used. Evacs decreased as telemedicine increased in data based projections.
	Program Description	No relevant references	N/A
Tools and Equipment	Evaluative Model	Ganguly and Ray (2000)	Interoperability of software systems at various levels is key to optimizing telemedical potential
Military Utility Extensive. Both human/machine interface and component "interoperability" (e.g., linkage of disparate databases across MTFs, specialties and remote treatment sites) are critical for effective operation.	Empirical Study	Mun, Levine, Cleary & Dai (1998)	Deployable teleradiology supported full MASH workload in Bosnian theatre and appears effective in reducing evacuations.
	Program Description	Birkmire-Peters, Peters, & Whitaker (1999).	Procedures for evaluating human factors and usability proposed.
Telemedicine Settings	Evaluative Model	1) Beach, Miller & Goodall (2001) 2) Filiberti, Wallace, Kateeswaran & Neft (1995)	The cost-effectiveness of telemedicine may be specific to the treatment setting. A telemedicine transaction model (TTM) can track the path of medical interventions from presentation to solution.
Military Utility Extensive. Evaluation of deployed treatment sites such as different ship types would permit effective adaptation of telemedicine capabilities.	Empirical Study	Whitlock et al., (2000)	Remote home monitoring of diabetics reduced physiological risk measures.

Program
Description

Cubano et al. (1999)

Successful case studies describe
telementoring laparoscopic surgeries on
USS Abraham Lincoln

Criteria for Assessment	Study Types	Representative References	Outcomes
Integration/Outcome	Evaluative Model	Griggby et al., 1995	Telemedicine impact determined by incidence of medical problem, diagnostic accuracy, potential for improving patient condition.
Military Utility Moderate. A model predicting the conditions where telemedicine would be most useful could measure potential impact in a deployed setting.	Empirical Study	1) Roine et al. (2001) 2) Walters et al. (1996)	1) Metaanalysis finds few strong evaluation studies. Existing data supports effectiveness of teleradiology. 2) 70% of telemedicine consults impacted patient status.
	Program Description	Burgess et al. (1999)	Development of telemedicine programs should follow needs assessment from patient population
Cost Analysis	Evaluative Model	Cameron et al. (1998)	Simulations used to project variables that lead to cost saving. Frequency of use was most important.
Military Utility Moderate. The military mission to provide care to troops anywhere supercedes cost factors. However, cost analysis is important in evaluating telemedicine as an alternative to MEDEVACS.	Empirical Study	Stoloff et al. (1998)	Store and Forward telemedicine projected to be cost effective for all Navy ship types. Teleradiology and VTC for large ships only.
	Program Description	None	N/A

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3.0 Applicability of Civilian Studies

Telemedicine is the use of telecommunications technologies such as videoteleconferencing (VTC), the Internet, email, and telephone to assist in delivering healthcare to remote or distant treatment sites (Bashshur 1995; Grigsby, Schlenker, Kaehny, Shaughnessy, & Sandberg 1995; Jerome et al. 2000). Reviews of the field's brief (30 year) history note that telemedicine systems evolve over time, vary across specialties, and require different evaluative foci at different stages of their development (Bashshur, Reardon & Shannon 2000).

As innovations in telecommunications make remote care more feasible and as systems mature, both military and civilian studies have begun advocating the development of a flexible model for evaluating more complex systems of remote healthcare delivery. Attempts to produce a model for systemic evaluation have called for standardization of evaluative criteria in the telemedicine field, but no model to date has been flexible enough to account for different practices across factors such as location, duration of system operation, different patient populations or medical specialties, and human-machine interface. Early (pre-1995) studies isolated specific factors to evaluate, either in anticipation of implementing a telemedicine system, or in assessing evolving systems in the early stages of their implementation. Most studies evaluated factors such as cost, usability, patient satisfaction, access, usage, or the selection, function, and performance of equipment in an effort to assess whether telemedicine would prove to be a viable healthcare option in a given scenario. However, a workable global or systemic approach has been elusive for both military and civilian researchers.

Evaluations of civilian telemedicine have often focused on telemedicine applications to rural treatment populations or prison populations, in part because early funding for telemedicine targeted those populations. Some recommendations from these studies may generalize to Navy telemedicine, since factors such as isolation (rural) or restricted movement or access to care (prison) can be characteristic of deployed military personnel, as well. As previously mentioned, another large body of literature describes applications of telemedicine to nursing, focusing on human factors that may parallel the experiences of Navy personnel such as IDCs, who provide healthcare on deployment, but don't possess MD degrees.

Bashshur (1995, 1998) raised several challenges for evaluating practices based on rapidly changing technologies:

- Variable costs and capabilities of telemedicine systems
- Limitations in current technologies (rather than in the practice of telemedicine itself)
- The tendency of studies to overgeneralize results from specific technologies to other, unrelated applications
- Midcourse changes made in operating parameters during the period of a study.

Bashshur concluded that a financially stable environment, regional networks, and the ability to redistribute resources in response to change should all be present if evaluation of a system is to be useful. Clearly, military healthcare is well situation to fulfill all of these capabilities.

Much like military telemedicine studies, the civilian literature assesses local implementations or specialty applications of telemedicine (Brecht, Gray, Peterson, & Youngblood 1996; Mekhjian, Warisse, Gailium, & McCain 1996; Lambrecht 1997; McCue et al. 1997; Houston and Rupp 2000; Zaylor, Whitten and Kingsley 2000). However, an important recurring theme in civilian telemedicine literature is the call for the development of specific categories for evaluating telemedicine as a comprehensive information system.

Military telemedicine sidesteps some of the main concerns of civilian applications, such as medical licensing or legal issues (Grigsby et al. 1995; Stanberry 2001)); state regulatory policies or political support (Weissert and Silberman 1996; Lipson and Henderson 1996); untrustworthy sources of information (Eysenbach & Diepgen 1998); the corporate or commercial structure of health care (Kleinke 2000; Shortliffe 2000; Sinha 2000; Jennett and Andruchuk 2001); community funding (Robinson 2000); unequal access to care for individual patients (Brodie, et al. 2000); and the effect of telemedicine on general practice (Thornett 2001).

Most military evaluations of telemedicine have focused on cost/benefit projections for developing a system of telemedicine, or on the implementation of telemedicine in a particular specialty or treatment setting. Tripler Army Medical Center in Hawaii has been especially prolific in producing telemedicine studies that deal with different treatment populations (Delaplain, Lindborg, Norton, & Hastings 1993; Cook, Hansen, Leckie, & Francoise 1995; Calcagni et al. 1996; Norton et al. 1996, 1997; Peters and Peters 1998; Birkmire-Peters, Peters, & Whitaker 1999; Burgess et al. 1999; Garshnek and Hassell, 1999; and Hill, Allman, and Ditzler 2001.) The need for a framework within which to interpret and utilize the Navy's own ongoing assessment is readily apparent (Garshnek and Hassell 1999).

A composite model that combines several criteria suggested in the civilian literature may be malleable enough to generalize across applications of telemedicine and may be further adapted to specific Navy applications. Further study is needed to determine whether each of these categories, or a combination of several of them, is relevant to military telemedicine.

4.0 Criteria for Assessing Telemedicine Systems

This section reviews representative models, program descriptions, and empirical studies (if available) performed or proposed within modified versions of each of Yawn's categories, adding a human factors component that many telenursing and telemental health studies propose.

4.1 Task Domain Studies

Task domain studies focus on the sensory perceptions of the user or the discrete tasks that make up complex processes. Visual and auditory components of medical tasks may be assessed in both conventional, face-to-face interactions and in interactions augmented with telemedicine equipment.

One of two structural models proposed by Grigsby et al. (1995) is an example of a task domain study. Grigsby et al. evaluated the processes by which a telemedicine system is integrated into traditional healthcare. This study

evaluated the costs, access, provider acceptance and provider use of telemedicine applications by types of process:

- Urgent evaluation
- Surgical follow-up
- Primary care consults
- Second opinions
- Transmission of diagnostic images
- Workups or medical data
- Management of chronic diseases
- Patient education

Grigsby concluded that classifying tasks allowed a more targeted evaluation of specific processes so that the data generated are more likely to generalize to other, similar tasks across specialties.

Military Studies of Task Domains

Potter, Zdyb, Smith, & Phillips (1997) evaluated data emerging from the U.S. Army's use of telemedicine for the civilian treatment population in Bosnia in 1995 as part of a peacekeeping effort connecting MASH units to Walter Reed AMC and NMCS. The authors stressed the need for training and technical field support and proposed a task-based model for assessing the effectiveness of deployed telemedicine in peacetime. The Health Care Complex Model analyzes healthcare "episodes" using five interactive modules:

- Demand Module - predicts requests for services
- Clinical Decision Module - applies clinical protocols to direct the flow of patients to service units
- Service Unit Capability Module - determines the capabilities of the combination of healthcare workers, technologies, and physical environments
- Service Unit Operations Module - assess the actual tasks providers perform
- Output Module - analyzes the effectiveness of the overall system in terms of cost, patient outcomes, and access to care.

Each module is further divided into several discrete tasks or areas of analysis, so that key components in a complex system of healthcare can be assessed according to the tasks each performs in support of the whole. VTC, teleradiology, email and ultrasound were all used. Eighty-one (81) telemedicine consults were conducted, the majority in dermatology (24.7%) and physical therapy (19.6%). Assessing data via this predictive model indicated that as telemedicine use increased, evacuations should decrease. The authors conclude that standard operating procedures should include careful organization of

technical support and telemedicine training to fit field medical business practices. This model may have application for telenursing possibilities.

Summary

Task domain studies may not be a helpful category for assessment in isolation from other components such as equipment utilization or human factors/training. However, task domain studies that focus on sensory perceptions can help identify training needs and describe the operation of telemedicine equipment to maximize return on investment. In addition, task domain studies that examine complex processes, rather than separate tasks, allow the separate components of a complex system to be assessed and may be useful in assessing technologies under development.

4.2 Assessments of Tools and Equipment

Equipment assessments analyze technical requirements, technical support, patterns of use, and performance of telemedicine equipment. Many studies combine equipment assessments with other types of studies, such as cost analyses or patient satisfaction surveys.

Ganguly and Ray (2000) evaluated models for interoperability-- the ability of software and hardware to exchange information and share tasks and resources-- in telemedicine software across treatment sites. Different software applications or hardware systems may have been purchased to deal with specific needs—tracking pharmacy inventory, doing electrocardiograms in a moving ambulance, patient billing, or archiving provider notes on patients. The study discusses increasingly sophisticated levels of interoperability, from basic physical interoperability, in which data can be manually transferred from one application to another, to semantic interoperability, in which a Knowledge Interchange Format (KIF) is designed to interchange knowledge among disparate software programs. Agent interoperability (an emerging capability) would allow mobile software agents to move from host to host and to interact with other software agents.

Anogianakis and Maglavera (1998) and Anogianakis et al. (1998) provided a detailed description of the equipment configuration for MERMAID, a EU financed, civilian project that provides telemedicine services to ships at sea in medical emergencies. Paramedics aboard merchant marine vessels follow medical guidelines based on the World Health Organization's International Medical Guide for Ships and utilize INMARSAT land-earth station links to medical teleconsultants. MERMAID combines mobile satellite and VSAT technologies and Integrated Services Digital Network (ISDN) protocols to provide global reach for marine telemedicine consults. The authors conclude that this combination of technologies comprises a global state-of-the-art system for providing quality care at sea.

Equipment Assessments in the Military

At Tripler Army Medical Center, Hawaii, commercially available telemedicine technology was assessed utilizing human factors usability criteria, such as technical acceptability, operational effectiveness, and clinical appropriateness in performing otological follow-up (Birkmire-Peters, Peters, & Whitaker 1999). User requirements in ENT and audiology exams were measured against the technical specifications of each product using direct observation of provider behavior and interviews with medical users. Training needs were assessed by videotaping clinicians performing required tasks, and analyzing task time, error rate, and user preferences. Interpretations of digital images captured with a video-otoscope were compared to examinations with a hand-held otoscope to assess the reliability, validity, and appropriateness of telemedicine equipment. Preliminary data indicated that procedures are sensitive to differences between testing instruments regarding the types of errors generated and the time taken to complete the exam.

Carlos and Pangelinan (1999) described assessments of telemedicine technologies performed by the Telemedicine Working Group in Tricare Region 10. The group focused initial test and evaluation efforts on telepathology and teledermatology, but found little user buy-in for telepathology. The current report is a descriptive summary of tests on specific products used in teledermatology, and the establishment of working relationships among users and technicians. Based on their experience with testing and evaluating teledermatology technologies, the authors of this study strongly advocated getting physicians directly involved in planning for and implementing telemedicine in their facilities.

An empirical study by Mun, Levine, Cleary, & Dai (1998) assessed data from the deployable teleradiology (DEPRAD) system installed in support of Primetime III to link MTFs in Bosnia and Hungary during 1995. The article examined the system configuration, integration and support, and telecommunications network that enabled the use of filmless teleradiology in over 10,000 radiological examinations during a 15-month period. This preliminary assessment outlined the success of implementing DEPRAD and indicated the feasibility of using teleradiology to support a full MASH workload in a deployed setting for the first time. Other advantages included avoiding land-based evacuations over hostile terrain. The disadvantages included considerable technical support early in the deployment and substantial transmission time (at least a few minutes), but this problem was expected to be worked out.

A projected structural model by W.J. Chimiak, Rainer, J.M. Chimiak, and Martinez (1997) examined the concepts and technologies needed to establish a telemedicine system for the entire Navy Fleet. The article detailed the structure and interrelationships among components of Navy telemedicine architecture and discussed a possible implementation scenario to promote remote medical care in the Fleet. Gomez, Karinch, and Zajtchuk (1996) described telemedicine support for humanitarian missions in Somalia, Croatia, Macedonia, Germany, Italy, Kuwait, Ivory Coast, Egypt, Panama, Virgin Islands, Kenya, and Haiti from Walter Reed Army Medical Center (WRAMC) in Washington, DC. The study

also analyzed data from clinical consults from February 1993 through February 1996 at WRAMC to assess the responsiveness of the telemedicine service. The study found that off-the-shelf equipment and low-bandwidth transmission could support multiple remote treatment sites simultaneously. The utility of digital still images with electronic medical records was also demonstrated.

Calcagni et al. (1996) examined the structural model of Phase I of the Primetime III system, which provided telemedicine support to the U.S. Army during Operation Joint Endeavor in Bosnia. The article used case reports to show the feasibility and effectiveness of telemedicine with shipboard and US-based medical departments. The majority of the consults assessed were in radiology; however, VTCs for ENT and dermatological problems were also examined. Several case reports show the clinical effectiveness of the consults and the importance of telemedicine training prior to deployment in the field. While this phase focused on pinpointing and solving technical glitches in the telemedicine system, the authors emphasized that human factors are a strong component of the overall success or failure of any implementation of technology. They recommended ongoing, standardized training, logistical support, and hands-on management of the organizational aspects of telemedicine to promote a sustainable telemedicine effort.

Summary

One of the most important research foci for the foreseeable future will be to address how technical configurations and organizational structures affect the flow of information and resources in a given telemedicine system. Both human/machine interface and component "interoperability" (e.g., linkage of disparate databases across MTFs, specialties and remote treatment sites) are critical for effective operation. Interoperability of software systems at various levels is key to optimizing telemedical potential. Evaluating the degree of technical interoperability and the organization's ability to pool knowledge and resources can help ensure that each system is deployed to its maximum capacity.

4.3 Evaluations of Telemedicine Settings

Although Yawn defined setting as primarily physical, evaluations of telemedicine settings can also focus on the social environment in which telemedicine is implemented. Physical assessments focus on material setup, technical skills, and user training. These assessments are often combined with cost analyses. Social models evaluate the human transactions or the social context in which medical care takes place.

Beach, Miller, and Goodall (2001) proposed an evaluation model that assesses costs, patient satisfaction, and equipment (VTC and store-and-forward) in an accident and emergency setting in the United Kingdom. This research combined a prospective case-control study with surveys of clinician, clinical staff, and patients to document treatment outcomes, resource allocations, and patient and staff willingness to use teleconsultations. Preliminary results indicated that the cost-effectiveness of a telemedicine system may be "situation-specific"; that

is, dependent on the social and clinical setting in which care takes place. Costs may change across specialties, treatment sites, patient population, and clinical staff. The success of a telemedicine system requires collaboration among key users of the system: technical staff, administrators, and users.

In the evaluation model proposed by Filiberti, Wallace, Kateeswaran, and Neft (1995), a Telemedicine Transaction Model (TTM) is described in terms of sites, personnel, and events. The model defines the elements of a medical intervention through the telemedicine system from patient presentation → data → consultant → data → disposition of the problem. For example, a patient might present at the primary exam with a particular set of symptoms, undergo labwork immediately relayed to a consultant via VTC, and receive a consensus diagnosis and treatment plan worked out between the primary physician and the specialist/consultant via VTC over a short period of time. Since the medical transaction is inherent in all applications of both conventional medicine and telemedicine, the model can be used at different levels of specificity—patient, program, site, condition, procedure, or outcome. Findings are easily understood across personnel functioning within the telemedicine system (administrators, providers, technicians, and other users).

Military Studies of Treatment Settings

In the Inpatient Psychiatry Unit at Tripler Army Medical Center, Hawaii, the utility of using VTC to bring geographically-remote family members into dialogue with patients was examined (Hill, Allman, and Ditzler 2001). Family members were linked with patients and their therapists via the VTC system sponsored by the U.S. Army Medical Information System and Services Agency. Social transactions among family members during VTC therapy sessions were described for two illustrative cases. Positive therapeutic outcomes were reported after VTC enabled patients to see and receive support from geographically remote family members. These case studies showed the feasibility of VTC consults and indicate that these sessions might have positive effects on patient disposition.

Clement, Brooks, Dean, and Galaz (2001) assessed outcomes at a telemedicine neuropsychology clinic that linked Brooke Army Medical Center, Fort Sam Houston, TX, with Army community hospitals. Initial assessments of patients with neurological disorders or brain injuries were completed at the medical center, while follow-up visits occurred at local Army hospitals via teleconferencing. Between mid-September 1998 and mid-May 2000, 32 patients were seen in 87 videoconferencing sessions. Several cases were discussed in which telemedicine consultation affected patient outcome. Telemedicine made it possible to determine whether soldiers with recent brain injury were fit for return to duty or should be separated from deployment. The authors noted that military telemedicine may serve as a model for the civilian community as well, having already dealt with issues such as informed consent, confidentiality, and medical practice across state lines.

Whitlock et al. (2000) performed a controlled study of home telemedicine consultation using nurse case managers in the treatment of diabetes patients in

clinics at the Eisenhower Army Medical Center. Patients in the telemedicine group attended diabetic education classes at the medical center, and experienced weekly telemonitoring visits by a case manager, during which blood glucose levels, weight, blood pressure, hypoglycemic episodes, exercise and nutrition goals, and well-being were reviewed. Physicians reviewed the patients once a month via teleconferencing, and the case manager, family practitioner, and internist communicated via email throughout the study. Patients in the control group were encouraged to attend the training sessions but given routine care for their condition. The study found that patients using telemedicine showed significant improvement in three key diabetic indicators: ADA, HbA_{1c}, and total body weight.

Hunter et al. (1999) performed a descriptive comparison of two teleoncology systems to outline the advantages and disadvantages of two technical infrastructures. The Pacific Oncology Outreach Project, an Internet-based system at Tripler for the most part used still pictures and live audio. Its goal was to avoid evacuations from outlying islands for healthcare. The Region 10 Integrated Cancer Network primarily utilized VTC, with the goal of promoting distance learning and collaboration among medical personnel. Technical aspects, participant satisfaction, and conference format were analyzed in both systems. The study found that, while both systems were successful and well accepted by providers, each system had distinct advantages. The Internet-based system at Tripler allowed users greater access, and the ISDN-based system minimized administrative tasks.

Cubano et al. (1999) examined outcomes of laparoscopic procedures telementored aboard the *USS Abraham Lincoln*. This was the first demonstration of this kind aboard a combat ship. The Battlegroup Telemedicine system is configured to link the *USS Abraham Lincoln*, the Johns Hopkins Applied Physics Lab, and Naval Medical Center at San Diego (NMCS D) via intraship, ship-to-ship, and ship-to-shore modalities. The authors discussed 5 cases in which ship-to-shore telementoring was used successfully in performing laparoscopic herniorrhaphies. This paper shows the clinical feasibility of using telemedicine for mentoring surgery by inexperienced providers in remote settings such as shipboard medical departments. Video links between the *USS Abraham Lincoln* and US-based naval hospitals such as NNMC and NMCS D allowed 5 laparoscopic surgeries to be successfully conducted with remote guidance by specialists. The study results suggested that successful telementoring depends on the working relationship between operating surgeons even more than on the hardware-software configuration.

A descriptive summary by Vidmar (1999) discussed the principles and history of teledermatology in the DoD. The article discussed evolving uses of telecommunications technologies in healthcare and briefly summarized the telemedicine experiences at several DoD sites, noting provider attitudes, problems with equipment, and staffing/training issues. The article concluded with a discussion of DoD sites that are evaluating the use of the World Wide Web for teledermatology and predicted increased use of teledermatology. This paper also reviewed evidence that store and forward teledermatology with high quality

digital pictures is as good as live VTC for clinical impact. The store and forward modality also has many advantages for scheduling and cost. The author stressed the need for systematic study of clinical impact rather than supporting anecdotal reports seen in many other studies.

Program descriptions by Bailey (1998) and a Website sponsored by Bakalar (1998) outlined the Multimedia Integrated Distributed Network (MIDN), a telemedicine initiative that linked two carrier battle groups, MTFs, and regional and remote clinics. Both sources reported the configuration of equipment and cited successful results of cases using telemedicine during the pilot phase.

Norton et al. (1996) described the early experiences of the telemedicine network established among the Tripler Army Medical Center, non-government agencies such as the University of Hawaii, and remote civilian treatment populations in Micronesia. This description encompasses applications reported in earlier articles and adds a description of additional treatment sites. The authors reported the establishment of a successful clinical consultation and health education network using low-bandwidth equipment and primarily preexisting communications systems. The consults may be useful for educational and professional interactions as well as clinical care.

A program description by Cook et al. (1995) briefly outlined the Tripler Army Medical Center's implementation of digital communications in teleradiology in the Pacific region using a "hub-and-spokes" model. Operation "Shooting Star" airlifts a Deployable Telepresence Unit (DTU) to remote locations and connects primary care providers and patients with Tripler's medical specialists via satellite or ground communications. Filmless radiology technology simplifies logistics and allows remote care in even harsh environments. Delaplain et al. (1993) described a pioneer telemedicine outreach effort conducted between Tripler Army Medical Center, Hawaii, and outlying small islands in the Kwajalein Atoll. The patient population is approximately 3,000 American workers under contract to the DoD. TRIPLER medical center provided remote VTC consults for 59 cases during the period of the study. Multiple specialties were used, and preliminary data indicated these consults helped avoid costly evacuations of patients. Fifteen evacuations were avoided, saving an estimated \$2000 per trip. Prior to the implementation of telemedicine in the area, specialty diagnosis and care often required a costly evacuation to Honolulu. Tripler physicians reported initial success in the first year of operation using telemedicine in 7 different specialty fields: dermatology, orthopedics, radiology, ophthalmology, urology, pediatrics, and physical therapy. The authors suggest that the telemedicine system will be cost effective.

Summary

The cost-effectiveness of a telemedicine system may be specific to the treatment setting. Evaluating the costs of implementing telemedicine in deployed treatment sites (for example, different ship types) would permit us to develop an investment strategy for the effective adaptation of telemedicine capabilities across sites. In addition, studies that track the path of medical interventions from presentation to solution can help develop straightforward criteria for correlating

the level of technology with the level of care needed at various treatment sites for a maximum return on investment.

4.4 Integration or Outcome Models

Integration models assess clinical outcomes in medical encounters in conventional and telemedicine settings. Outcomes can be assessed within a particular specialty or condition, or tracked over an entire system to indicate the efficacy of telemedicine for diagnosis and treatment.

Roine, Ohinmaa, and Hailey (2001) completed a comprehensive review of evaluation models in the telemedicine literature according to strict criteria for inclusion. Articles reviewed had to assess outcomes of the use of telemedicine in terms of administrative changes, patient outcomes, or economic effects. In addition, studies had to compare the use of telemedicine with conventional alternatives in a scientifically valid manner. Thus, articles that described specific telemedicine initiatives or assessed the feasibility of a particular application were omitted from review. Roine and colleagues began with 1,224 studies between 1966 and 2000. Fifty (50) met criteria for review. Most of these (34) included clinical outcomes, while the remaining sixteen (16) were mainly cost analyses. Strong evidence for clinical effectiveness was found for specialties such as teleradiology, teleneurosurgery, and telepsychiatry. Teleradiology was supported as a cost savings speciality, but more evidence is need to evaluate other specialties for cost savings. The authors concluded that, while telemedicine has demonstrated success in some specialties and applications, scientific data for appropriate evaluation of telemedicine continue to be sparse. Therefore, broader applications of telemedicine should be restricted at this time.

One of two structural models for evaluation that Grigsby et al. (1995) proposed evaluates the diagnostic effectiveness of telemedicine. This model focuses on the types of conditions that might be considered productive indicators of clinical effectiveness. Accurate diagnoses in conditions that have relatively high incidence, are moderately difficult to diagnose, and that pose a significant risk/benefit and relief from suffering are good indicators of the effectiveness of telemedicine compared to face-to-face consults. The authors advocated assessing the effectiveness of telemedicine for a limited number of diseases and relative access to care in order to evaluate medical effectiveness. Their companion model, proposed for use in conjunction with the outcome analysis, evaluates telemedicine usage by task (Section 4.1).

Military Integration/Outcome Studies

Burgess et al. (1999) assessed the structural model used in the application of telemedicine to otolaryngology in a research and residency training setting in the Department of Surgery at Tripler Army Medical Center. Both military personnel and civilians in the Pacific Island Nations are referred to Tripler Army Medical Center for otolaryngological problems. TRIPLER's approach to developing telemedicine programs was reviewed, beginning with needs assessment, evaluation of appropriate telemedicine technologies and deployment

of new systems. The authors of this study advocated using VTC and store-and-forward technology to increase patient access to specialty clinics, reduce costs incurred from remote off-island treatment referrals, reduce the isolation of remotely based providers, and assist in medical training. They also identified the need for specialty speech care in remote clinics and are in the process of studying the effects of live versus VTC speech therapy on outcomes for patients. If there are no substantial differences, telespeech therapy could be deployed as the standard of care.

Navein, Hagmann, and Ellis (1997) assessed outcomes of telemedicine consults in Army peacekeeping operations in Macedonia. Referring and consulting physicians completed questionnaires, and follow-up interviews of referring physicians were conducted. The study found that the availability of telemedicine reduced the number of evacuations, saving \$180,000 to \$300,000 and approximately 30 workdays for the period January 1994 to April 1995. Telemedicine consults also were found to affect treatment in 30 of the 47 cases studied. Provider satisfaction was rated high (89%), with the providers most familiar with telemedicine technologies the most likely to utilize them. Sixty percent of consults led to changes in case management, including treatment, mostly in dermatology cases. Twenty six percent of evacuation decisions were affected by the use of telemedicine. The authors advocated further application of telemedicine, supported by user training and equipment upkeep. Pretraining of providers on the telemedicine systems was thought to be critical to success in the field.

Walters (1996) assessed the clinical utility of telemedicine in consultations from deployed military medical units in Somalia, Haiti, Croatia, and Macedonia during the period February 1993 to March 1995. A retrospective case review was performed by physicians to assess the severity of illness, the communication modality utilized for the consultation, and changes in diagnosis, treatment, or duty status of the patient due to the consultation. Diagnoses were affected in 30% of cases, treatment in 32%, and overall patient status in 70% of consults. This demonstrates the feasibility of deployment telemedicine in the field. Noting that this retrospective study was based on data not originally designed to be evaluated (an important factor in many military studies), the author recommended establishing a formal structure of oversight to ensure adequate training, standardized procedures, and maintenance of equipment.

Summary

Telemedicine has been integrated successfully in several specialties, most notably radiology and ENT. In fixed treatment settings (i.e. brick and mortar facilities), telemedicine can increase remote access to care, reduce costs incurred from remote treatment referrals, reduce the isolation of remotely based providers, and assist in medical training. In deployed settings, telemedicine technologies can reduce the number of evacuations and lower the cost of providing an appropriate level of care. A model predicting the conditions where telemedicine would be most successfully integrated could measure potential impact in deployed as well as fixed treatment settings.

4.5 Cost Analyses

Cost analyses are understandably the most prevalent in the telemedicine literature, especially in the early days of widespread adoption and implementation. Most focus on projected or real-time costs for installation, maintenance, and usage of telemedicine equipment. Savings or costs avoided may also be considered. As existing telemedicine systems age or technology changes, cost analyses can also be performed to assess cost of equipment replacement and retraining of users.

McCue et al. (2000) conducted a retrospective analysis of 3 years of data to measure the cost per visit of VTC telecardiology services and non-telemedicine cardiology services for patients from a Virginia correctional setting. Differences in costs/savings were measured in these categories:

- Medical (tests, facility fees)
- Labor
- Nonlabor (such as T-1 lines)
- Transportation
- Total annual costs

The study found that telecardiology can generate savings with increased utilization of services. The feature of telemedicine that allows cost reduction over time is fixed operational costs.

A.E. Cameron, Bashshur, Halbritter, Johnson, and J.W. Cameron (1998) suggested a simulation model for projecting the financial performance of a mature telemedicine system, even in the early stages of development, and with limited empirical data. A computer simulation for estimating the financial patterns of a hub-and-spokes telemedicine network was developed and tested in the MDTV program in West Virginia. The model simulated real-world situations in which decisions are made within model variables and parameters. This paper develops a model for projecting telemedicine savings relative to in-person care, as empirical data on this question are lacking. The model shows substantial savings are possible, but results vary with the assumptions of the model. A critical assumption is frequency of use: more use of a telemedicine system leads to more savings. Telemedicine programs therefore need to reduce barriers to telemedicine use to enhance the financial success of telemedicine.

Brunicardi (1998) assessed actual costs in a pilot telemedicine program that connected a university medical center with the medical facilities in the Ohio prison system. Costs associated with the use of two-way interactive video to deliver health services were compared with those incurred without the use of telemedicine. In addition to direct costs associated with telemedicine equipment and operations, the study stressed the need for assessment of indirect savings in transportation, correction officer time, and security surveillance when taking prisoners into the community for healthcare. Straightforward cost analysis obscures costs that are avoided in telemedicine health care. Assessing both costs incurred and costs avoided resulted in modest per-visit and quarterly savings in the pilot prison telemedicine project. Zincone, Doty, and Balch (1997) performed

a similar empirical analysis of costs in North Carolina State Prison, with similar recommendations. This paper proposed a method for determining the "break even point" where the telemedicine service paid for itself. In this case, the system reached "break-even" after two years of operation. Importantly, the "break-even" point can be affected by the rate of usage or excessive costs for telemedicine equipment or personnel.

An analysis of structures for evaluation by Sisk and Sanders (1998) addressed specific challenges to telemedicine evaluators: joint costs, multiple uses, expansion of use beyond original intentions, and technological innovation that alters telemedicine systems even while they are being evaluated. This framework for the economic evaluation of telemedicine would assess three criteria: quality, accessibility, and efficiency of care.

Military Cost Analyses

Stoloff, Garcia, Thomason, and Shia (1998) estimated costs and projected equipment and bandwidth requirements for the implementation of telemedicine aboard more than 300 Navy ships. The study assessed patient visits over a one-year period in order to estimate both the potential savings and the clinical impact that of a telemedicine system might have enabled over that period. An additional survey of shipboard medical personnel indicated a possible substantial savings from a lower incidence of medevacs through the use of telemedicine consults. The providers determined that telemedicine would have enhanced care in about two thirds of all consults. Modeling revealed that store and forward telemedicine would be cost effective on all ships and submarines and VTC only for carriers and amphibious ships. Teleradiology would be cost effective only for carriers. Seventeen percent of medevacs would have been prevented with telemedicine. The study concluded that the use of email, fax, and the Internet would be cost effective on all types of Navy ships. Larger ships could support VTC and some digital diagnostic instruments. Giving shipboard medical personnel access to ship communication capabilities would cost less than relying on a commercial satellite. Overall, telemedicine would improve quality of care and help reduce the incidence of medevacs.

Garcia and Stoloff (1997) estimated the peacetime need for telemedicine for ships at sea and assessed costs and benefits of several types of applications. Four telemedicine technologies were analyzed: email, Internet, VTC, and a digitizing scanner added to existing x-ray equipment. The incidence of medevacs was reconstructed using a self-administered survey of shipboard medical departments. A panel of physicians and IDCs considered 8,000 medical encounters from the Snap Automated Medical System (SAMS) to determine which cases would have benefited from telemedicine consults. The study found that the net savings of telemedicine over traditional medicine was relatively small, some \$35,000 per ship. However, another finding was that implementing telemedicine in the Fleet could improve the quality of life for sailors and promote Fleet readiness. The authors advocated assigning more bandwidth to shipboard medical departments.

Summary

While of course the military mission to provide medical care to troops takes precedence over bottom line considerations of cost, cost analysis is important in evaluating telemedicine as an alternative to conventional methods of care to maximize return on investment. Cost analyses in isolation from assessments of other criteria are too limited to provide a good prediction of return on investment, however. A straightforward investment strategy that takes into account treatment setting, level of care, level of telemedicine suite, and other factors in addition to costs should be developed so that the appropriate level of telemedicine can be implemented in each setting.

4.6 Evaluations of Participant Satisfaction

Evaluations of participant satisfaction focus on the patient's level of comfort with the telemedicine medical transaction, or on provider perceptions of and potential usage of telemedicine. Patient and provider satisfaction studies can be used to predict telemedicine usage. In general, findings from satisfaction evaluations have been quite positive, perhaps because the study participants were those already inclined to accept teleconsults. Telemedicine studies often note that experience with or exposure to teleconsults is associated with positive attitudes toward telemedicine (Walters 1996, Karp et. al 2000). Interviewing only those who had already decided to use telemedicine as a provider or patient excludes those who may have decided not to use telemedicine or those who were undecided. Thus, a true random sample of patients and providers without selecting for telemedicine experience might reveal more overall skepticism.

Mair and Whitten (2000) identified 32 empirical patient satisfaction studies for review. The review concluded that studies to date have not accounted for the underlying reasons for patient satisfaction or dissatisfaction. Few studies used strong methodology or carefully developed questions to address important telemedicine issues. In addition, methodological deficiencies may make results in many studies nongeneralizable. Methodologically rigorous research into patient and provider attitudes toward telemedicine is recommended.

Sixsmith (2000) evaluated data on patient satisfaction with technologies designed to create a home monitoring system for geriatric patients. A field study of 22 subjects between ages 60 and 85 tested an intelligent home monitoring system. Sensors measured the level of activity over a given period of time; behaviors such as time out of bed or use of the refrigerator; room temperature; and unusual activity that could indicate a fall or other distress. Although a large number of false alerts were generated during the study period, and no real emergencies occurred, participants reported feeling safer. Thus, patients with a large personal stake in being perceived as autonomous and independent were willing to work with deficiencies in current technologies in order to receive perceived benefits, a factor that may prove helpful in predicting help-seeking behaviors and the usage of telemedicine in settings where autonomy and competence are highly valued.

At least two studies found provider dissatisfaction with telemedicine. May et al. (2001) analyzed structural changes in a mental health clinic after the introduction of a videophone for psychiatric consultations. Interviews with mental health practitioners, general practitioners, and patients suggested that telemedicine had limitations for some patients (e.g., extreme anxiety) and that specialists were most wary of its limitations for care. Most providers believed experience with the system would allow them to adapt to provide effective care. However, after an initial period of enthusiasm, providers increasingly and actively resisted the technology. Practitioners attempted to augment their established models of practice, rather than using the technology to create new models. Importantly, the system was ultimately rejected, not because of technical limitations, but because users could not make it conform to the medical transaction model already in use.

In another study evaluating structural models for telemedicine usage, May and Ellis (2001) found that staff perceptions about the purpose, design, and service of a proposed telemedicine clinic undermined their attempt to obtain funding, even as they agreed on the need for the project being proposed. While no data or outcomes were achieved, this study points out the importance of user buy-in and participant satisfaction with telemedicine systems even in the planning stages. May and Ellis conclude that human perceptions of what capabilities and functions a system should address is as important to the success of a telemedicine system as the technology, itself.

Military Patient or Provider Satisfaction Studies

Participant satisfaction is often cited as one factor among many in military studies of telemedicine. The authors have not found a dedicated study of participant satisfaction in the military telemedicine literature.

Summary

Participant satisfaction measures the human “return on investment” in a telemedicine system. This is important for military studies in two key areas. First, the self-diagnostic capabilities telemedicine provides may increase help-seeking behavior and preventive care in settings where autonomy and competence are highly valued. Second, the successful implementation of a technology depends in large part on the perception of users that it is useful. Any strategy for estimating the level of telemedicine needed at a particular level of care should take into account how the technology will change, eradicate, or clash with practices already in place. Money and personnel hours are wasted if technology is perceived as an additional tasking rather than as a tool for managing workload more effectively.

4.7 Human Factors Evaluations

Human factors evaluations overlap many of the preceding categories. Studies assess any of the following:

- Human/machine interaction

- Provider/patient transactions
- User training or development of preference for one modality over another
- Development and promotion of viable telemedicine systems

A structural model by Yellowlees (1997, 1998) discussed telepsychiatry in Australia and proposed core human factors principles in developing successful telemedicine systems. Central in this model is a focus on the provider perceptions of "ownership" or ego investment that drive the establishment and development of workable systems. Decisions based on management policies, equipment parameters, patient need, or medical specialty are not as likely to promote a coherent and viable telemedicine system as policy built around the needs and interests of early adopters. Care providers and users who enthusiastically adopt telemedicine applications work actively to support, promote, troubleshoot, and otherwise strategize the ongoing development of the overall system. These early adopters provide a solid, tangible base from which to expand implementation of telemedicine.

Human Factors in Military Studies

Human factors tend to be assessed as part of a larger cluster of factors in military telemedicine studies. This suggests that the organizational aspects of telemedicine in a military setting could be explored in more detail.

A structural model proposed by Eliasson and Poropatich (1998) suggested a constellation of quality management (QM) tools to promote performance improvement (PI) in telemedicine systems. Five categories of telemedicine management at WRAMC are described and proposed as guidelines for other telemedicine programs:

- Licensing and credentialing
- Security and privacy
- Consent
- Peer review
- Tailored efforts to improve performance

Summary

Any model for calculating the level of telemedicine to implement in a given treatment setting should include an assessment of human factors. Provider investment in and ease with telemedicine is critical for program success: user understanding of a system's capabilities can determine whether or not a telemedicine system is utilized to its fullest capacity. Assessing human/machine interaction, provider/patient transactions, and user training can also help insure what an Army researcher recently called "the critical issue": that the technologies implemented in a given setting assist rather than encumber medical personnel in performing their duties (Reed 2002).

5.0 Recommendations for Future Studies

As telecommunications technologies evolve and proliferate, they are becoming more and more an unremarked backdrop to everyday healthcare practices in both military and civilian settings. Medical training for care providers is increasingly specialized, allowing personnel the ability to utilize the more sophisticated capabilities of telemedicine systems across a continuum of care. Thus, research that assesses how telemedicine should be implemented, how much it may cost, who uses it, what treatment outcomes it enables, or even a combination of these categories, may have run its course. The focus of current telemedicine research should now shift from asking "How do telemedicine configurations work in a military setting?" to "What level of telemedicine should be implemented to achieve the maximum return on our investment?"

Military telemedicine systems vary widely, both in treatment facility and in the clusters of technologies they utilize to deliver care. Levels of telemedicine capabilities do not easily correlate to levels of care: several different telemedicine suites may be implemented in a single echelon. The continuum of treatment sites ranges from highly mobile to wholly fixed sites, with different combinations and levels of telemedicine technologies available for implementation within different levels of care. Many times, what drives the success of the implementation of telemedicine is not the setting or level of care, but rather the specialized training and investment of the personnel using it. (See Figures 2 and 3).

Figure 2 Telemedicine Technology Suites

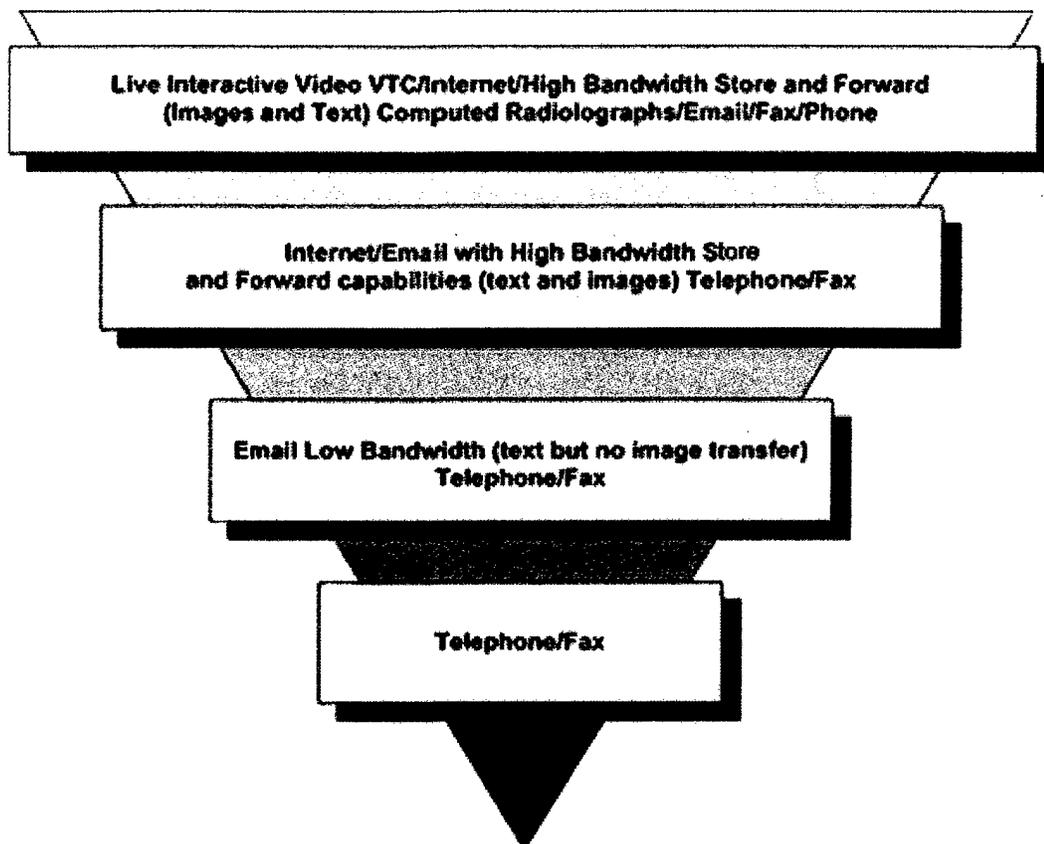
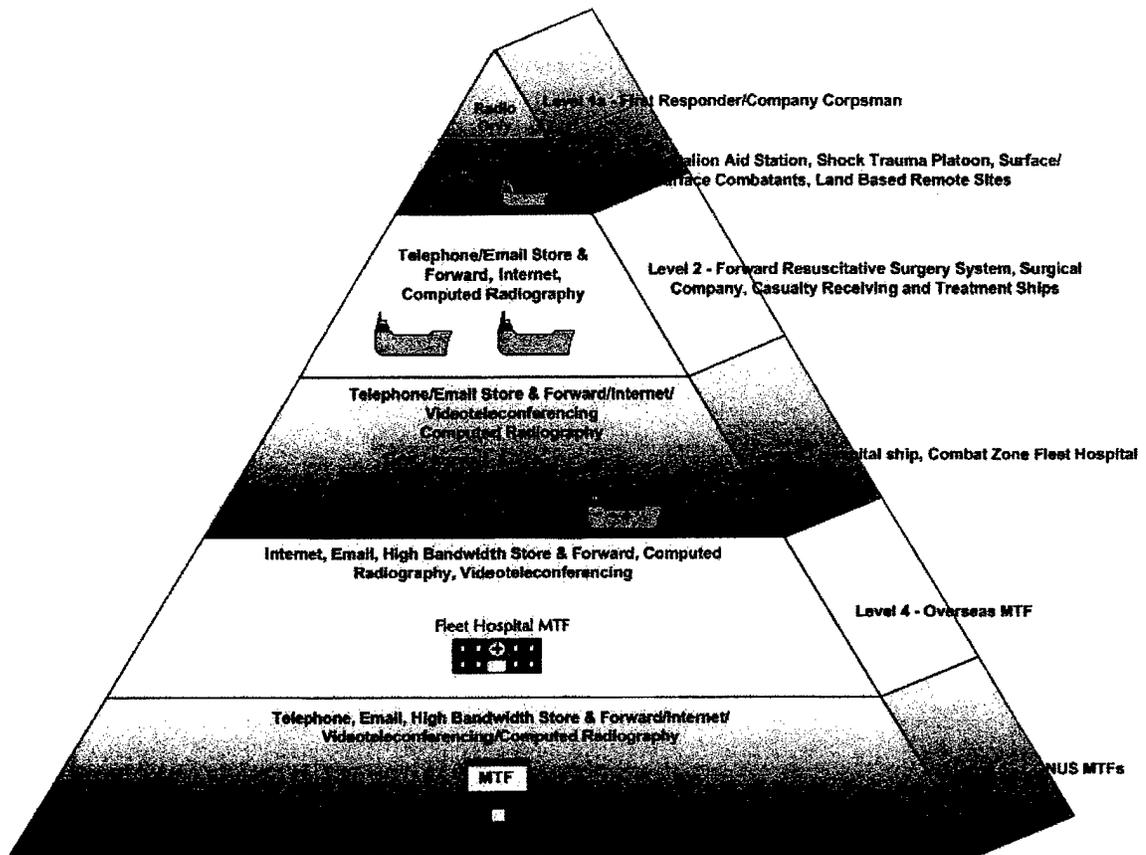


Figure 3 Technical Capabilities Across Treatment Sites



Levels of Care and Associated Telecommunications Capabilities

With complex systems and variable treatment sites, individual studies can focus on only one or two of the multiple components operating within a telemedicine system. Even a series of narrowly-focused short-term studies will not produce an accurate picture of how well the overall system is functioning. However, a series of narrowly-defined short-term studies can begin to produce an accurate picture of how levels of telemedicine correlate to levels of care. These results can be codified to develop a model for determining the type of telemedicine suite to implement across variable treatment sites, levels of connectivity, levels of care, and patient needs. Such a model can help ensure that funds are invested in the most effective way to serve our forces. Two suggestions for baseline studies to develop a workable model follow.

5.1 A Technology-Based Approach for Classifying Telemedicine Systems

The emerging focus of Navy telemedicine studies should be to develop a classification system for assessing telemedicine systems based on technical capabilities. This could be accomplished with a series of short-term studies that test the utility of telemedicine in a particular setting. This approach would isolate a small telemedicine system in which multiple components might be assessed as parts of a functioning unit. For example, military clinics might be classified by their telemedicine capabilities. A continuum of capabilities could be established, with fully equipped telemedicine facilities at one end and clinics with minimal telecommunications resources at the other. Each class of clinic could be assessed based on outcome measures such as clinical impact, operational efficiency and integration of various components of the system with overall clinic functioning.

The simplest method for classification of clinics is to rank their telemedicine capabilities from basic to advanced technologies. Thus, the basic telemedicine suite for a clinic might consist of telephone and fax for remote consultations. More advanced classes of telemedicine suites would consist of added technologies such as email, Internet, computed radiography, various other diagnostic videoscoping procedures (e.g., ENT otoscope) and live videoconferencing. Important variables such as medical staffing at each clinic, patient population, and geographic location could also be assessed and isolated statistically to permit a controlled comparison of clinics on the outcome measures described above. A technology-based approach for classifying and evaluating functioning telemedicine systems could be developed from the findings of these studies.

5.2 Assessing a Pilot Telemedicine System or Site

A single pilot system or site could be used to test structural models for assessing Navy telemedicine as a complex healthcare delivery and information system. A systemic evaluation of telemedicine in a pilot system or "node" would allow researchers to analyze how the seven evaluative categories discussed in this report function in relation to each other and to the larger system.

For example, the Medical Data Surveillance System (MDSS), an R & D product currently under development that looks for trends in patient encounter data, could be evaluated as a closed "telemedicine" system. Each of the seven components for evaluation discussed in this technical report can be assessed within the MDSS system: Task domains, Tools, Settings, Integration, Costs,

Participant satisfaction, and Human factors. These components can be assessed in two ways. First, each component can be evaluated as part of the MDSS system as a whole to determine how effective individual factors operate within the larger system. Second, the interoperability of these seven components can be assessed to determine the cumulative or systemic effect of all seven components.

Following are some issues to be addressed:

- How efficient is the overall system?
- How does each component interact with and affect each of the others?
- How does each component fit into the system as a whole?
- If one or more components is not functioning at full capacity, how does that effect the efficiency of the overall system?
- Are any of these elements working against each other?

Alternatively, a specific site could be assessed as one "node" in a complex information system that gives us information about how the larger system functions. In particular, researchers would analyze the procedures and organizational structures for proposing, implementing, assessing, and "growing" telemedicine applications within the test site.

Focus groups could develop a framework of evaluative criteria applicable to the test site. The framework of evaluative criteria that emerges from focus group discussions would be used to assess telemedicine studies already completed or in progress at the test site, as well as develop future projects and assess the growth and health of the telemedicine system at the test site. Some components to consider in each of the seven evaluation categories are as follows:

- Assessment of current research/efficacy of telemedicine at the test site
- Criteria for judging proposed research or areas to implement telemedicine
- Criteria for assessing which projects should get the green light
- Structures and procedures for assessing work in progress (projects as they develop)
- Structures for generating written reports of work in progress
- Structures for promoting completed or successful projects to the larger telemedicine community
- Ongoing assessment of the overall health of the telemedicine project

Researchers can craft this systemic evaluation as an analysis of organization (a structural analysis with no data); a set of empirical studies of the components at the test site; or a combination of the two, based on available funding and time frames.

Appendices A and B outline possible structures for preliminary focus group discussions and short-term studies that can be used to determine criteria for a working model for assessing telemedicine as a complex system. Preliminary studies are the first step in developing a model to determine which levels of telemedicine correlate to specific levels of care.

6.0 Conclusion

An analysis of civilian and military models for evaluating telemedicine indicates that a straightforward model for calculating military telemedicine's return on investment should be developed. There is currently no workable model for evaluating telemedicine as a system, either in military or civilian research. While military telemedicine circumvents some problems faced in civilian systems, issues such as wait and queue, connectivity, continuum of care across treatment sites, and care needs in deployed platforms make it difficult to measure the effectiveness of military telemedicine at different echelons of care. A model should be developed that dictates the appropriate telemedicine suite to implement for a given population at risk across varying treatment facilities so that the maximum return on investment can be achieved.

As Navy telemedicine responds to emerging technologies and shifts in care needs, it is likely that current concerns such as bandwidth requirements or image quality will become non-issues, new applications will arise, and care will extend to more remote treatment populations. A method to evaluate the complex structure and organization of telemedicine should be developed to provide consistent parameters within which to interpret and utilize the system as it matures and further evolves. With troops deployed in remote, austere, and relatively inaccessible environments, technical, human, and organizational components across the system must enable the free flow of information to assure quality of care. Evaluating the structure of the overall system, as well as its components, can help realize the potential for interoperability and enable quick response to current defense needs.

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Appendix A
Preliminary Focus Group Discussions

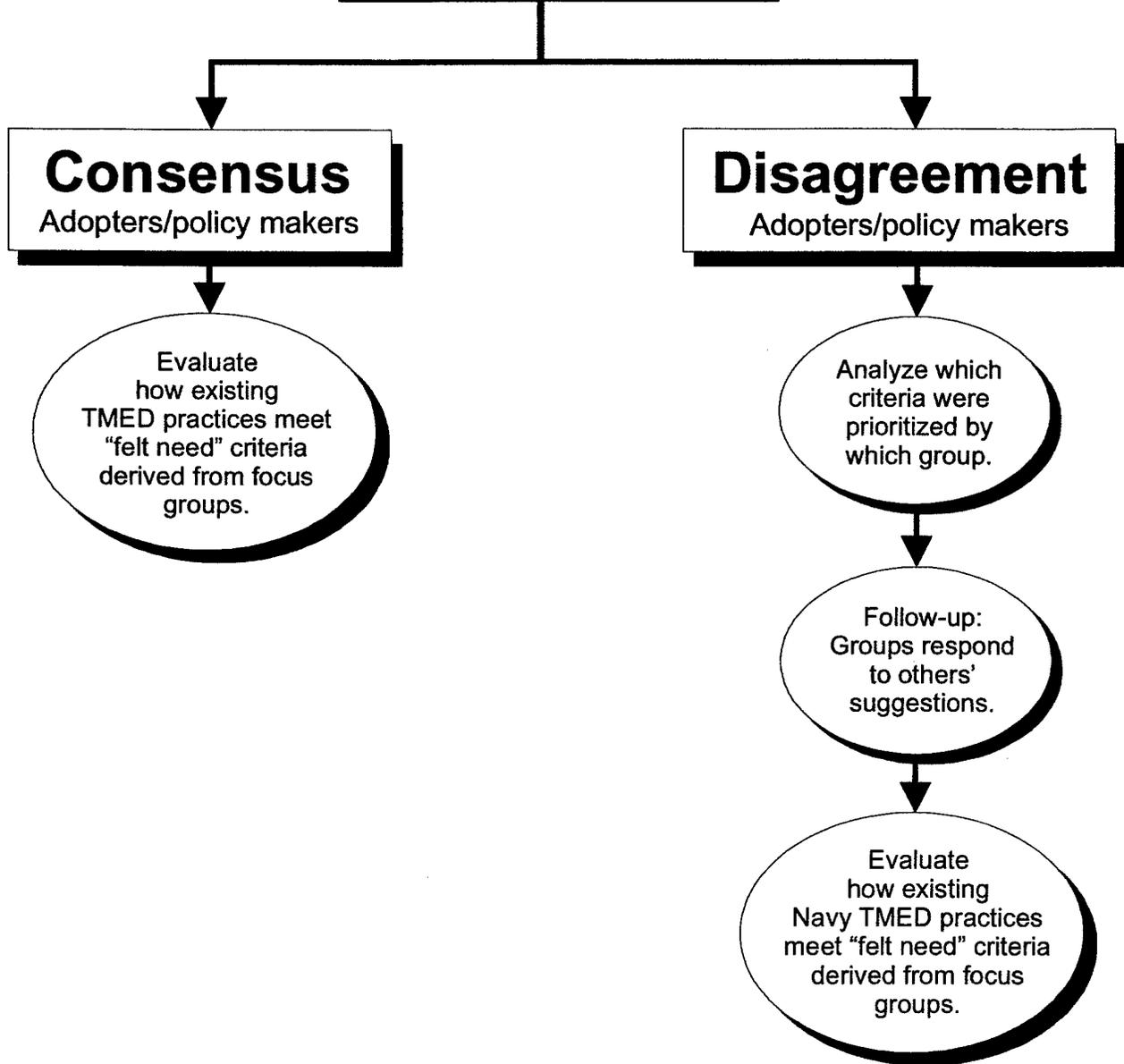
A preliminary study of criteria to include in a model for assessing a pilot telemedicine system or site can be conducted with focus groups. Initial focus groups would be comprised of the early adopters and policy setters who implement telemedicine at the treatment site or make strategic decisions about the management of telemedicine in the Navy. This composition of groups would allow feedback from both on-site users and administrators. Participants would be provided with the set of evaluation categories described in this report and asked to rank how important each of these categories is in evaluating Navy telemedicine. Categories, or items within categories, could be added or deleted. Focus groups composed of both on-site users and administrators would follow their ranking and assessment with a discussion of recommendations for evaluating each category.

A working model for assessing telemedicine on a structural or systemic level would be developed from consensus reached in these preliminary focus group discussions. Further studies (as recommended in Appendix C) could assess one or more of these criteria as components within the overall framework of Navy telemedicine, or evaluate how the different components work in relation to each other and the system as a whole.

Overview of Preliminary Focus Group Discussions

Step 1	Early telemedicine adopters (providers) and policy makers (administrators) rank criteria set out by relevant models of evaluation in the telemedicine literature.
Step 2	Focus group results are formed into a framework of evaluative criteria applicable to Navy telemedicine.
Step 3	The framework of evaluative criteria that emerges from preliminary focus groups will be used to develop further studies, as described in Section 5.0 of this report. These studies will be used, not only to assess the components of Navy telemedicine, but also to refine the model for evaluating Navy telemedicine as a healthcare system.

Focus Groups



Appendix B

Categories for Continuing Short-Term Studies

Appendix A recommends a start-up study to develop criteria for evaluating Navy telemedicine as a complex healthcare system. A systemic evaluation model could be developed to provide a framework for interpreting current Navy telemedicine within system-wide goals and concerns. Following are recommendations for studies in each of the categories described in this report.

Task Domains

To date, NHRC evaluations of telemedicine have focused primarily on applications by specialty, treatment site, or clinical outcomes. A task-based, process-oriented model could delineate the categories of processes or tasks involved in Navy applications of telemedicine across specialties. This would allow the evaluation of Navy telemedicine as a system of processes or tasks, rather than its integration into discrete specialties, such as Ear/Nose/Throat (ENT) or radiology. Clinical outcomes for diagnosis and treatment could also continue to be assessed at the level of condition, specialty, or treatment setting.

Tools and Equipment

Component interoperability is *extremely* important for field readiness and ongoing Navy medical research. A military assessment of interoperability would evaluate the functions of the existing components of military telemedicine purchased from various vendors to propose solutions for data exchange. Key areas of assessment would include:

- Standards or formats
- Operation and translation
- Effectiveness across variations in software, hardware, user, and site.

Component interoperability is critical to ongoing research and field readiness.

In addition, a human factors usability evaluation could assess the use and effectiveness of telemedicine equipment already purchased and in operation. Criteria to consider might include the following:

- User needs
- User satisfaction
- Rate of use of equipment
- Perceived limitations of the existing system
- Reliability of current equipment (reflected in clinical outcomes)

Commercially available equipment could also be assessed utilizing criteria developed from user surveys. A model for evaluating both existing and commercially procurable equipment could be designed from user survey results and human factors usability criteria, such as technical acceptability, operational effectiveness, and clinical appropriateness for Navy medical applications.

REPORT DOCUMENTATION PAGE

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1. Report Date (DD MM YY) Jul 02	2. Report Type Final	3. DATES COVERED (from - to) Sep 01 to Aug 02
4. TITLE AND SUBTITLE Navy Telemedicine: Current Research and Future Directions		5a. Contract Number:
6. AUTHORS Cheryl Reed; Ralph Burr & Ted Melcer		5b. Grant Number:
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) Naval Health Research Center P.O. Box 85122 San Diego, CA 92186-5122		5c. Program Element: 637060N
8. SPONSORING/MONITORING AGENCY NAMES(S) AND ADDRESS(ES) Chief, Bureau of Medicine and Surgery Code M2 2300 E St NW Washington DC 20372-5300		5d. Project Number: M2332
		5e. Task Number: 001
		5f. Work Unit Number: 60004
		5g. IRB Protocol Number: 32211
		8. PERFORMING ORGANIZATION REPORT NUMBER Report No. 02-35
		10. Sponsor/Monitor's Acronyms(s) BuMed
		11. Sponsor/Monitor's Report Number(s)

12 DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release; distribution unlimited.

13. SUPPLEMENTARY NOTES

14. ABSTRACT. (maximum 200 words)

Problem: The ongoing war on terrorism makes medical surveillance and remote access to medical care for deployed forces pressing concerns. The potential for chemical and biological terrorism on U.S. soil adds an urgency for Navy medical technologies to respond to Homeland Defense concerns. An assessment of Navy telemedicine as a complex healthcare support system is needed to demonstrate how current practices, training, equipment, and expenditures measure up to the emerging needs of the Fleet.

Objective: This report reviews military and civilian models for evaluating telemedicine systems in order to determine future directions for Navy telemedicine research within the current funding environment. How can we calculate the level of technology to implement for the most productive return on investment across varying treatment settings?

Approach: A literature review of military and civilian telemedicine was conducted in September 2001 to determine what types of evaluative models are currently being advocated by telemedicine practitioners. A review of current models for evaluating telemedicine yielded seven categories for evaluation: tools and equipment; outcomes; cost; treatment settings, task domains; participant satisfaction; and human factors. Using this literature review as a baseline, the authors developed a conceptual model for assessing the structure of Navy telemedicine. The model describes how each of the seven components affect the implementation of telemedicine in Navy and civilian settings. Finally, the authors recommend how short-term, narrowly-focused studies could form the basis for a model for correlating level of technology suites to level of care across treatment settings.

Results: An analysis of models for evaluating telemedicine indicates that there is currently no workable model for evaluating telemedicine as a complex and multi-level system, either in military or civilian research. While military telemedicine circumvents some problems faced in civilian systems, issues such as wait and queue, connectivity, continuum of care across variable treatment sites, and healthcare needs in deployed platforms make it difficult accurately to measure the effectiveness of telemedicine at different levels of care.

Conclusions: A model for evaluating telemedicine that correlates level of technology to level of care should be developed. A system of measurable criteria for determining the appropriate telemedicine suite to implement for a given population at risk across varying treatment facilities needs to be designed so that the maximum return on investment can be achieved.

14. SUBJECT TERMS
Telemedicine systems, military and civilian personnel; models for evaluating telemedicine; treatment facilities

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGE	18a. NAME OF RESPONSIBLE PERSON
a. REPORT	b. ABSTRACT	c. THIS PAGE			Commanding Officer
UNCL	UNCL	UNCL	UNCL	45	18b. TELEPHONE NUMBER (INCLUDING AREA CODE) COMM/DSN: (619) 553-8429